24 GHz Short Range Radar for Automotive Applications

Siemens VDO Vehicular Radar System

before the
Federal Communications Commission

January 31, 2003

SIEMENS VDO
Automotive

FCC visit January 31, 2003
24 GHz Short Range Radar

SARA

Traffic scenarios

Need for accident prevention

"A death from vehicle crashes every 13 min. (injury every 14 sec.)
41,200 motor vehicle deaths per year."
(National Safety Council, *Injury Facts,* 1999)

Statement of U.S.A. National Transportation Safety Board Public Meeting - 1 May 2001:

"Develop and implement .... a program to inform the public .... on the benefits, use, and effectiveness of C.W.S. and A.C.C."

(C.W.S. = collision warning system; A.C.C. = adaptive cruise control)

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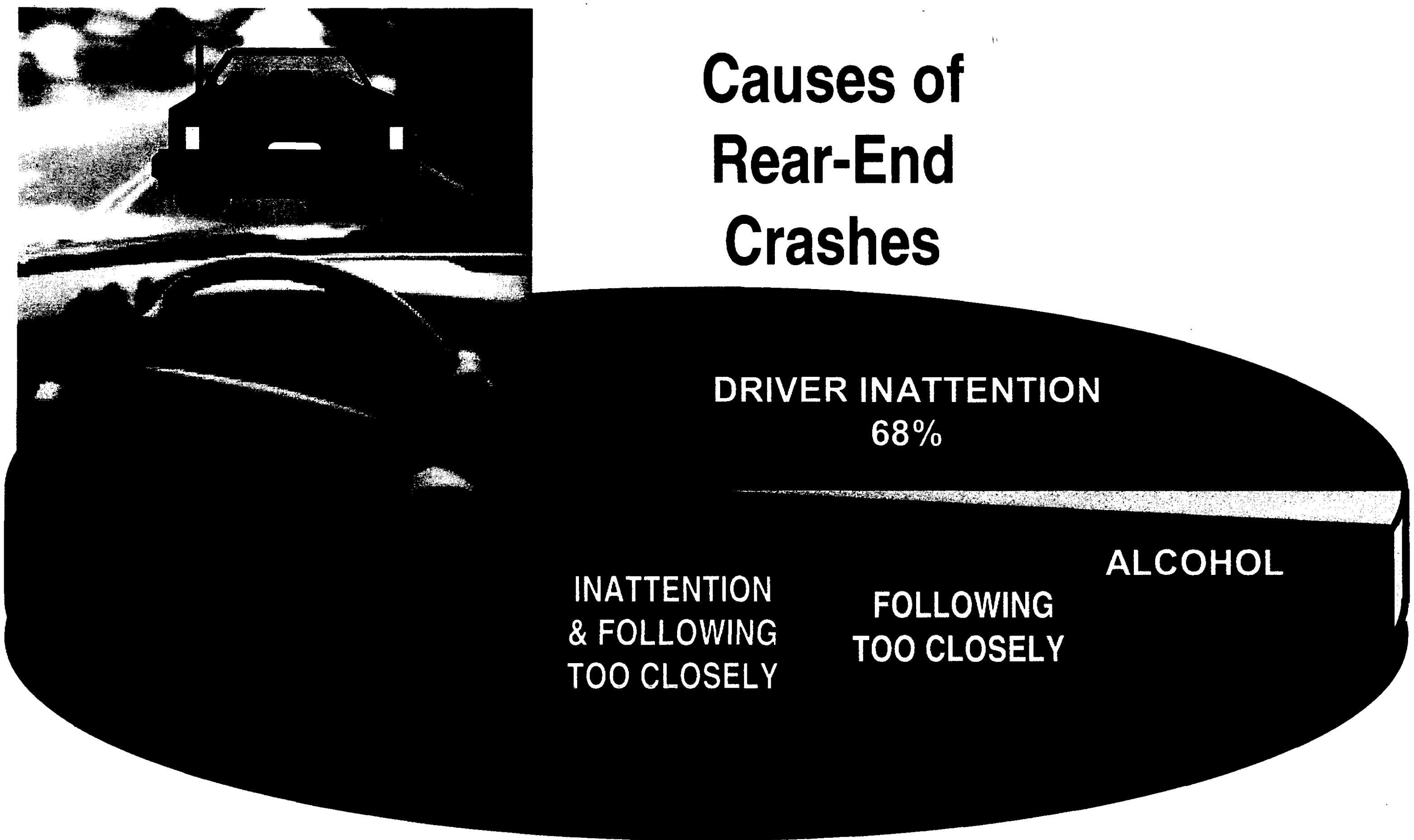
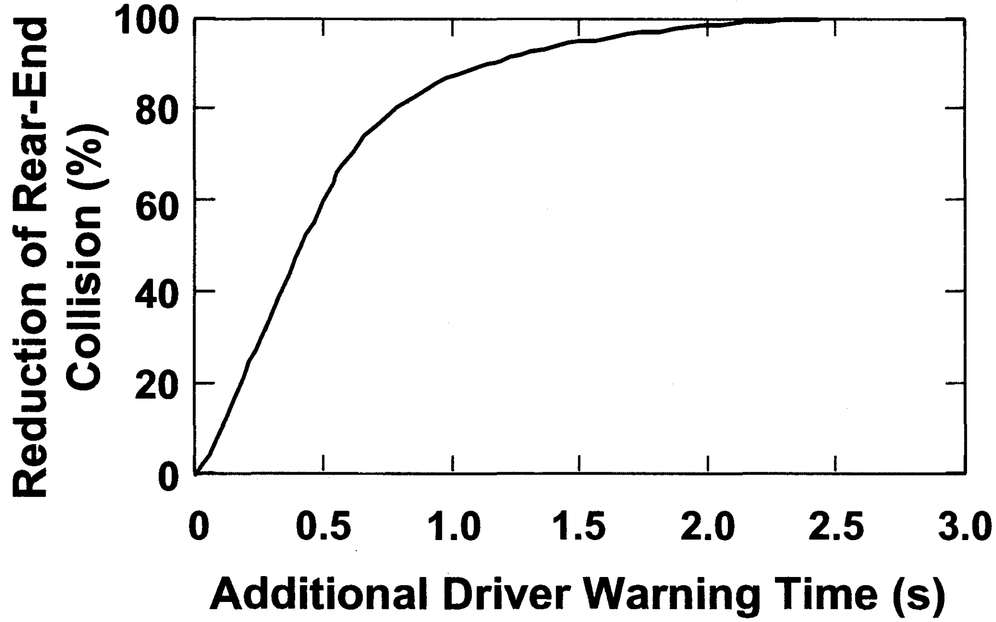
SARA

Causes of Rear-End Crashes



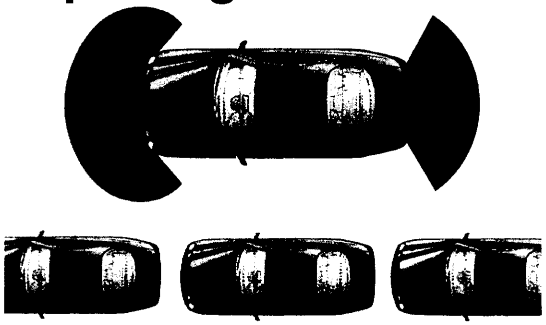
Source: NHTSA

- **"Roughly 37 to 74% of rear-end crashes are theoretically preventable by the use of headway detection systems"**
  - **Source:** R. Knipling, et al.; *Assessment of IVHS Countermeasures for Collision Avoidance: Rear End Crashes*, U.S. Dept of Transportation (NHTSA Technical Report HS807-995), Springfield, VA, 1993.
- **"Providing a driver with an additional 1-second of warning time to react can reduce rear-end collisions by nearly 90%"**
  - **Source:** Cited Daimler-Benz investigation, as reported by: Bill Siruru, "Do Collision Warning Systems Reduce Accidents", UTS, Sept/Oct 1998.

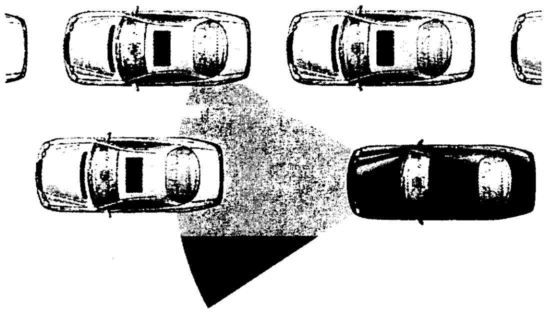


Fields of application

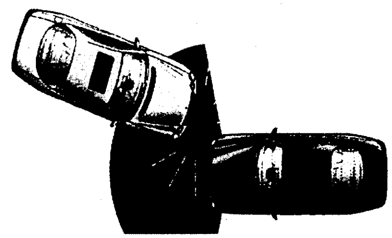
- **parking situations**



- **dense city traffic**



- **PreSafe™**



Siemens VDO Automotive vehicular radar basic operational modes:

1) Only motion detection operating in the Field Disturbance Sensor band pursuant to 47 CFR § 15.245 within the specified limits

2) Low resolution, far range (up to 30m) distance and speed measurement pursuant to 47 CFR § 15.249 within the specified limits

3) High resolution, near range (up to 4m) distance and speed measurement pursuant to 47 CFR § 15.209 within general emission limits

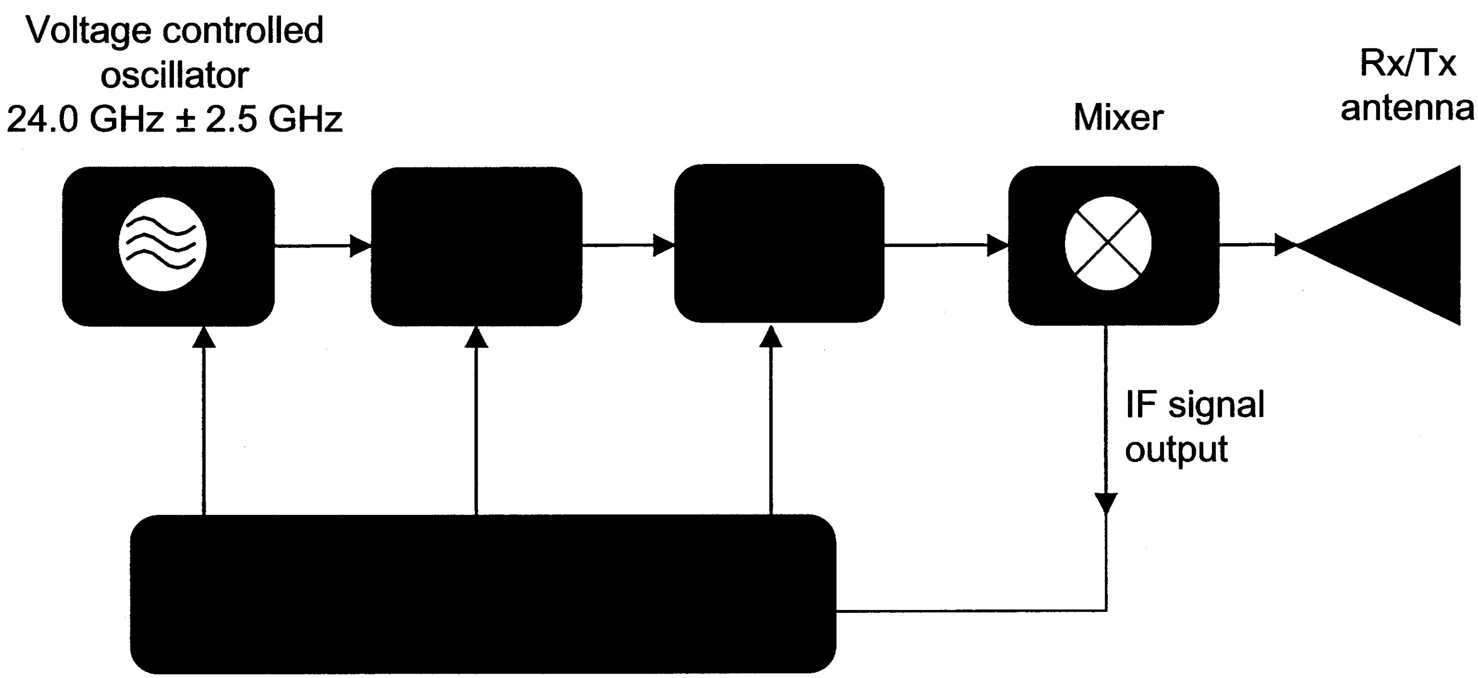
Possible methods for achieving high resolution radar:

- **Very short pulse width:**
  Implementation method:
  Pulsed systems that operate by rapid switching (**typ. 1 ns**) of a fixed carrier or even without any carrier at all.

- **Shifting of the carrier frequency over a large frequency range:**
  Implementation method:
  Frequency Hopping (FH) systems that operate by rapidly hopping over a large frequency range over a set time period (**up to 400 000 000 ns**), which results, on average, in a broadband signal.

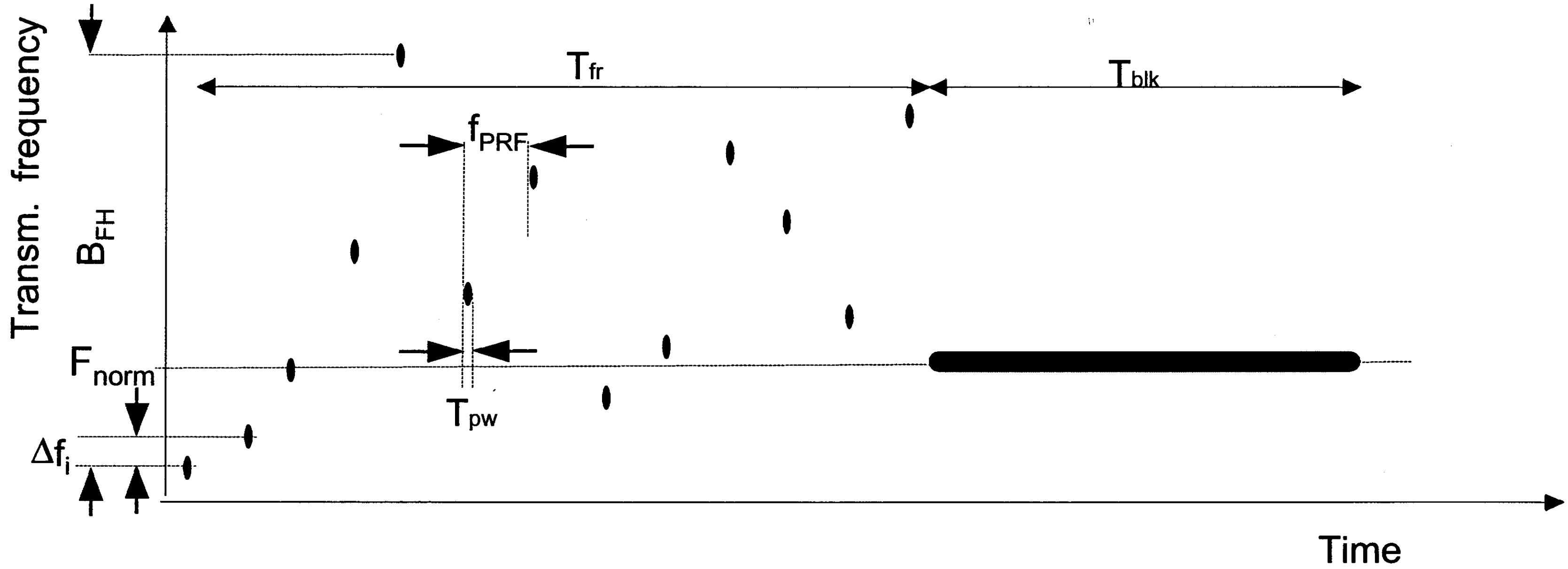
- **Combination of pulsed and frequency hopping system (=pulsed FH):**
  Implementation method:
  Only intermittent (**typ. 50ns**) frequency changes of the carrier, resulting in a kind of independent time and frequency multiplexing technique.

Basic functional diagram of pulsed FH radar:



Microcontroller controls VCO span, HF pulse, duty cycle and Doppler Booster amplification

Typical pulsed FH modulation form with parameter definitions :



T_{pw}:	transmitter pulse power duration
f_{PRF}:	Pulse repetition frequency
Δf_i:	hopping channel carrier frequency separation
T_{fr}:	Frame time period
T_{blk}:	Blanking period (for Doppler measurement)
F_{norm}:	Nominal operating frequency for fixed carrier (Doppler measurement)
B_{FH}:	Occupied bandwidth (DSB $_{-10\,dB}$) with $n * \Delta f_i = B_{FH}$

Siemens VDO Pulsed Frequency Hopping System
Salient System Parameters

PARAMETER	DEF	MIN	TYP	MAX	UNIT	REMARKS
Operating Characteristics						
Nominal operating frequency	F_{norm}	24.075	24.125	24.175	GHz	For Doppler in ISM/SRD band
Operating range for pulsed FH mode	F_{range}	22		29	GHz	According to R&O FCC 02-48
Frequency hopping bandwidth	BW_{FH}	0.5	1	5	GHz	Symmetrical or asymmetrical around F_{norm}
Avg. power EIRP for Doppler mode in F_{norm}	P_{AVG_D}	0	20	32.73	dBm	Pursuant to 47 CFR, § 15.245 (i.e. 2.500.000 µV/m @ 3m)
Avg. power EIRP for pulsed FH mode in BW_{FH}	P_{AVG_FH}		-50	-41.3	dBm	According to R&O FCC 02-48 RMS measurement with 1MHz RBW
Peak power EIRP for Doppler mode in F_{norm}	P_{PK_D}		20	32.73	dBm	Pursuant to 47 CFR, § 15.245 (i.e. 2.500.000 µV/m @ 3m)
Peak power EIRP for pulsed FH mode in BW_{FH}	P_{PK_FH}	-23.5	-8	0	dBm	According to R&O FCC 02-48 P_{PK_FH} measured in 50 MHz RBW
Mean Power Spectral Density in BW_{FH}	PSD_{mean}		-110	-101.25	dBm/Hz	PSD_{mean} is within a 10 ms timeframe absolutely flat
Pulse Width	T_{pw}	5	50	300	ns	Results in a spectral spread of max. 200 MHz per pulse
Duty Factor	k_{duty}	0	12	30	dB	In Doppler mode CW operation with k_{duty} = 0, in pulsed FH mode a crest factor up to 30 dB
Pulse Repetition Frequency	f_{PRF}	10		2000	kHz	
Frame time period	T_{fr}	2	10	20	ms	i.e. time of a complete cycle where all frequency hops have occurred exactly one time
Blanking time period	T_{blk}	0	5	10	ms	Used for Doppler measurement at fixed carrier F_{norm} in ISM/SRD band
Hopping channel carrier frequency separation	Δf_i	1	10	50	MHz	i.e. frequency change between two consecutive hops

Siemens VDO 24 GHz Vehicular Radar - Interference Analysis

- For the pulsed FH radar the same emission limits (peak power, average power, etc.) imposed for pulsed UWB systems would apply.
- Application of the same peak and mean power emission limits results in the same level of interference potential, regardless of modulation.
- Pulsed FH systems achieve similar mean power spectral densities as pulsed UWB systems with a peak power EIRP below 0 dBm.
- The overall (time and frequency) duty cycle of pulsed FH can be in excess of 30 dB, resulting in very low mean power values. Thus, the pulsed FH system is by design limited by the peak power value of 0 dBm/50 MHz (or -24.5 dBm/3 MHz).
- With a peak power limit of -24.5 dBm/3 MHz and a mean power limit of -41.25 dBm/1 MHz, a minimum margin in the spectrum analyzer reading of 16.75 dB from peak to mean is sufficient to attain the UWB mean power limit.
- The pulsed FH system produces a smoothly distributed mean power spectral density within one complete frame period without any further dithering (i.e. no line spectrum).

Siemens VDO 24 GHz Vehicular Radar - Interference to EESS

- EESS was the only service identified in the NTIA interference analysis.
- The only parameters that are relevant to the interference analysis are the mean power of the vehicular radars and the number of sensors.
- EESS is not affected by the type of modulation used by the vehicular radar systems for two reasons:
  1) Integration time of EESS (typ. several milliseconds) is too long to make distinctions between different types of modulation.
  2) Spatial integration over a large footprint (several thousand units).

Scope of UWB Rule Modification / Waiver Request

- Modify/Waive Section 15.503(d) (defining a UWB transmitter as "an intentional radiator that, at any point in time . . . has a UWB bandwidth equal to or greater than 500 MHz . . . ") to allow the Siemens system to occupy the required 500 MHz bandwidth within 10 ms.

- Modify/Waive language contained in paragraph 32 of the UWB Report & Order to allow the Siemens system to be measured with the frequency hop active.

- Modify/Waive Section 15.521(d) to the extent it requires that the RMS detector measurement of average emissions be based on a one millisecond or less averaging time. A longer averaging time (e.g., 10 ms) would result in more accurate measurements.

Rationale for Changing / Waiving UWB Rules

- The requirement contained in Section 15.503(d) that a UWB transmitter must "at any point in time" have a bandwidth equal to or greater than 500 MHz is unnecessary to protect passive services in the 23.6 to 24 GHz band. Unlike existing services in other bands, the modulation of the vehicular radar is not relevant to assessing the potential for interference to EESS in the band.
- The requirement contained in Paragraph 32 of the UWB Report and Order that frequency hopping systems be measured with the frequency hop stopped is not necessary.
  - The average power of the Siemens system with the frequency hopping active can be measured with the use of a RMS detector.
  - These measurements are accurate and reliable, and demonstrate compliance with the FCC's UWB rules.
- If the 1 millisecond or less averaging time established in Section 15.521(d) is strictly applied in measuring the Siemens system, the measurements of average power recorded will not be as accurate as allowing for a longer (e.g., 10 ms) averaging time.

Rationale for Changing / Waiving UWB Rules

- **Grant of the waiver request would allow Siemens to develop a potentially life-saving technology.**
- **The Siemens system has no practical alternative to emitting into the 23.6-24.0 GHz band.**
  - Designing the Siemens system to hop over the 23.6-24.0 GHz band is technically not feasible.
  - The Siemens system is a dual mode (Doppler and UWB) device. Operating with a center frequency at 24.125 GHz (where Siemens can take advantage of the higher power limits available for Doppler applications in the ISM band) is essential to the reliability of the Doppler function.
  - Siemens' competitors will be allowed to emit into the 23.6-24.0 GHz band under the FCC's UWB Rules.
  - Siemens is working with SARA on a European allocation that is harmonized with the U.S. UWB rules. If Siemens cannot take advantage of such harmonization, it will be at a severe competitive disadvantage.

Rationale for
Changing / Waiving UWB Rules (cont.)

- **Grant of the modification/waiver request would not result in a greater potential for harmful interference to passive services than that contemplated in the FCC's UWB Rules.**
  - Siemens is willing to accept all the conditions contained in Section 15.515(c) requiring the attenuation of power by vehicular radars into the 23.6-24.0 GHz band.
  - NTIA derived these conditions, and the FCC imposed them, based on assumptions about the aggregate level of emissions resulting from 24 GHz vehicular radars, including the Siemens vehicular radar, and not based on the emissions from any particular modulation technique or technology.
  - Grant of the Siemens request would in no way undermine the framework established by the FCC and NTIA to ensure the protection of passive services.

Conclusions

- From an interference perspective, there are no relevant distinctions between the pulsed FH system developed by Siemens and pulsed UWB systems.
- Existing UWB rules unnecessarily prevent certification of the Siemens vehicular radar as a UWB device.
- Siemens' pulsed FH can be accurately and reliably measured with the frequency hopping active using a spectrum analyzer RMS detector.
- In this instance, modification/waiver of the relevant UWB rules is justified because it would not increase the potential for harmful interference and is in the public interest.